NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE INTEGRATION OF A SMART STAGE INTO CURRENT DIVE SHIPS OF THE NAVY

by

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June 2013

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704–0188*
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1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2013	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE THE INTEGRATION OF A SMART STAGE INTO CURRENT DIVE SHIPS OF THE NAVY			**5. FUNDING NUMBERS**
6. AUTHOR(S) Thomas O. O'Bryant III			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943–5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The Navy's Dive and Salvage community is interested in upgrading their current dive stage. The present dive stage is a basic steel cage that is primarily used as a mode of transport from the surface of the water to a maximum depth of 300 feet. How would a new SMART stage system that incorporates lighting, video feed and hydraulics into the cage affect the operational effectiveness of the dive and salvage community? Can this new system be integrated into current dive ships? What are the impacts for variation of requirements for integrating this system in to current ships? This thesis will serve as a proof of concept for integrating a SMART Stage dive cage onto current naval dive ships. This will be performed by conducting a stakeholder analysis of the system to ensure that it meets or exceeds the needs of the dive and salvage community. In addition, a functional requirements analysis will be conducted for integration of the system.

14. SUBJECT TERMS Dive, Salvage, SMART Stage, Dive Stage, T-ARS, T-ATF			**15. NUMBER OF PAGES** 71
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540–01–280–5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

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THE INTEGRATION OF A SMART STAGE INTO CURRENT DIVE SHIPS OF THE NAVY

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 2013

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The Navy's Dive and Salvage community is interested in upgrading their current dive stage. The present dive stage is a basic steel cage that is primarily used as a mode of transport from the surface of the water to a maximum depth of 300 feet. How would a new SMART stage system that incorporates lighting, video feed and hydraulics into the cage affect the operational effectiveness of the dive and salvage community? Can this new system be integrated into current dive ships? What are the impacts for variation of requirements for integrating this system in to current ships? This thesis will serve as a proof of concept for integrating a SMART Stage dive cage onto current naval dive ships. This will be performed by conducting a stakeholder analysis of the system to ensure that it meets or exceeds the needs of the dive and salvage community. In addition, a functional requirements analysis will be conducted for integration of the system.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARS	Auxiliary Rescue Ship
ATF	Auxiliary Tug Fleet
CONOPS	Concept of Operations
FFBD	Functional Flow Block Diagram
FSW	Feet of Salt Water
GO-CO	Government-Owned Contractor-Operated
INCOSE	International Council on Systems Engineering
LARS	Launch and Recovery System
MDSU	Mobile Dive and Salvage Unit
MOE	Measure of Effectiveness
MOP	Measure of Performance
MRC	Maintenance Requirement Cards
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
SOP	Standard Operating Procedures
SUPSALV	Supervisor of Diving and Salvage

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EXECUTIVE SUMMARY

The U.S. Navy is investigating replacing their current diving platform with a SMART stage. The current stage is a barebones platform installed on T-ATF and TARS class of ships. This stage provides divers with transportation to and from underwater dive sites with use of the ship's davits. The stage is only capable of transporting divers and their equipment and does not serve any other function. The dive and salvage community expressed a need for a new system with added SMART capabilities. The SMART capabilities are defined as additional equipment that is added to the stage that can help in the monitoring of the worksite and divers and equipment that aids the divers in mission completion. This new SMART dive stage will also need to be modular and able to be integrated into both the T-ATF and T-ARS class of ships.

From stakeholder analysis, requirements were generated and it was determined that the new SMART stage will need to be equipped with an assortment of monitoring equipment. The addition of lighting, cameras, sonar, pressure and current sensors would be needed to accurately monitor the divers in the water as well as their surroundings. With the addition of the added monitoring equipment, there would also need to be a control station onboard the ship to process all the incoming data. This control station would require more ship space to effectively operate the SMART stage.

In attempting to find the best solution for a SMART stage, various alternatives were generated through a morphological box style of decision making. Four alternatives were selected for further analysis. The four alternatives selected were keeping the current system in place, modify the current system, purchase a commercial launch and recovery system (LARS) or completely fabricate a new system. Each alternative was then analyzed and ranked based on three grading criteria. These grading criteria were defined as the ease of system integration, requirement satisfaction and system performance. Each criterion was then broken down into smaller elements. These elements were each given weighting values accounting for each criterion having its own ranking of importance. The overall criteria weighting values were; ease of integration 40%, requirement satisfaction 40%, and system performance 20%.

After each alternative was analyzed the best fit solution was found to be a modification of the current system. This system, though not meeting all requirements, was able to provide the stakeholders with the best solution that balances ship integration, requirement satisfaction and system performance. This SMART stage would provide the dive and salvage community with the added capabilities of monitoring divers and their surroundings improving diver effectiveness.

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ACKNOWLEDGMENTS

I would like first and foremost to thank Professor Cliff Whitcomb for all of his guidance and support thought out my thesis process. In addition, I would also like to thank Professor Fotis Papoulias for taking the time to be my second reader and Ms. Barbara Berlitz for her help reviewing my work. All three have been great teachers and mentors during my time here at the Naval Postgraduate School and I thank you. I would also like to thank my thesis processor Ms. Susan Hawthorne for all of her hard work reviewing my formatting and her corrections. Last but not least I must also give thanks to my loving and supportive wife, Cheri, and our wonderful son, Tommy. Cheri, thank you for putting up with me during this stressful time and checking over my writing, love you.

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I. PROBLEM DEFINITION

A. INTRODUCTION

The Navy is currently exploring ideas for developing a new SMART stage dive system to be used on its dive and salvage ships. The Navy presently employs a dive stage that is comprised of a stainless steel cage, which has the capability of lowering and raising two fully rigged divers into waters as deep as 300 feet. The current system is effective and very simple in design, but it offers no information about the divers' surroundings to the support crew on the surface nor does it aid the diver in his or her job while at the operating site. The Dive and Salvage community is exploring the idea of a SMART Stage diving system that will not only be a means of transporting the divers to and from the depths but will also integrate a number of systems into the cage that would better assist the divers in the water as well as the support crew above. The new system will be used primarily on the T-ATF-166 (Powhatan class) ocean towing ships and the T-ARS-50 (Safeguard class) Salvage ships. With the added capability of integrated communications, lighting and other sensors the proposed SMART stage will better equipped to ensure the safety of the divers in the water and improve mission capability.

B. PROCESS DESCRIPTION

A systems engineering approach was key to completely defining the problem and generating requirements that would then drive the design process. For its simplicity and document driven approach, the waterfall systems engineering process model was chosen for this project. Each step in the waterfall process (Figure I-1) includes verification of prior work before moving on to the following step. This project incorporates the first three steps of this waterfall process, and a generic description of each is given below:

<u>Step 1: Requirements:</u>

a) Determining project scope

b) Functional decomposition of issue to be resolved

c) Determination of all relevant stakeholders

d) Scenario development through demonstration, driving-force, and system change type scenarios to capture all required system framework
e) Creation of functional and process flow models to depict functional flow.
f) Requirement review

Step 2: Specifications:

a) Develop trade spaces and analyse options from requirements
b) Choose best options
c) Develop quality standards from requirements
d) Document thoroughly
e) Specification review

Step 3: Design:

a) Determine any required new technologies to be developed
b) Develop new technologies
c) If there are no new technologies to be created, incorporate old technologies in a thoughtful manner
d) Proceed through iterative, rejection/approval, cycles of engineering design
e) Final design approval

The design step for this particular problem began with the current Dive Stage System by analyzing its capabilities and how it is used on the T-ATF and the T-ARS ships. From there, the above steps were followed to determine acceptable alternatives for the SMART stage. These alternatives were then ranked based upon ease of integration with current ships and overall requirement satisfaction from the users' aspect.

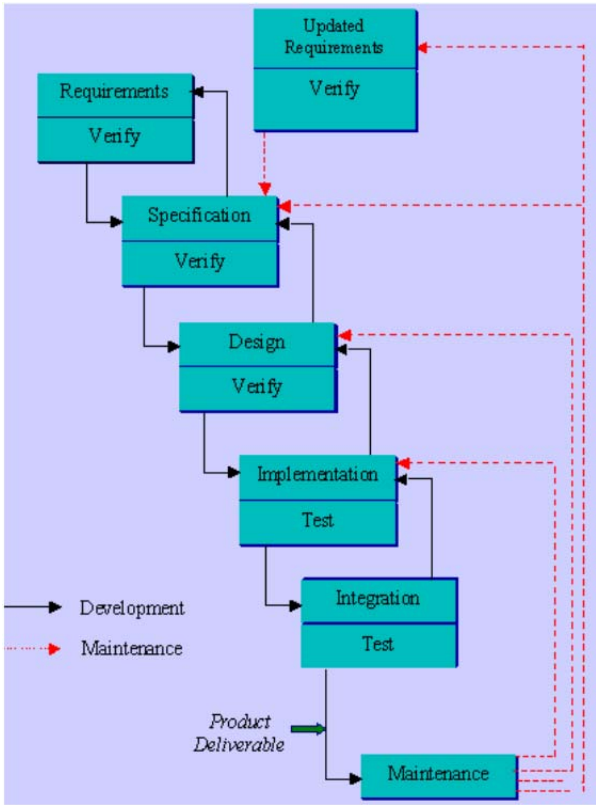

Figure 1. Waterfall SE Process Model (SE3100, 2011)

C. BACKGROUND

Prior to scoping the problem and setting the constraints, research into the current dive and salvage ships, diving stages, diver equipment and working environments was performed.

1. Dive and SalvageShips

A salvage ship's primary mission is to perform combat salvage, emergency repair, and firefighting. The Military Sealift Command (MSC) currently has two classes of salvage ships that are deployed around the world. The first class of salvage ships is the T-ATF-166 Powhatan class ocean-going tugs, and the second is the T-ARS-50 Safeguard class salvage and rescue ship. Each class of ship has a number of integrated onboard systems that make them a highly capable platform, able to conduct a wide range of salvage, rescue, and towing missions that are critical in sporting naval operations around the world.

a. T-ATF (Fleet Ocean Tug)

Military sealift command’s four fleet ocean tugs are USNS Catawba, USNS Navajo, USNS Sioux and USNS Apache. These ships provide the Navy fleet with towing service with the ability to tow Navy vessels as large as battleships. When augmented by Navy divers, fleet ocean tugs assist in the recovery of downed aircraft and stranded or grounded ships. In addition, when carrying specialized equipment, the fleet ocean tugs can perform submarine rescue operations (Service Support: Fleet Ocean Tugs). These ships are operated under a contract that is as defined as a Government-Owned Contractor-Operated (GO-CO) vessel, and T-ATFs are located around the world (Southworth 2008).

Figure 2. USNS Mohawk T-ATF 170 (“USNS Mohawk (T-ATF-170) underway”).

Although the T-ATF class of ships are often involved in dive and salvage operations, they do not have any diver’s life-support systems integrated into their systems. Therefore, when assigned to dive and salvage missions, a detachment of the Mobile Dive and Salvage Unit (MDSU) must bring on all the gear necessary to complete a given mission. Table 1 is a listing of the basic T-ATF ship specifications.

T-ATF Fleet Ocean Tug	
Length:	226 feet
Beam:	42 feet
Draft:	15 feet
Displacement:	2,260 long tons
Speed:	15.0 knots
Civilian:	17 civil service mariners
Military:	4
Operation:	Government-owned/ Contractor Operated

Table 1. T-ATF Specs (Service Support: Fleet Ocean Tugs).

b. T-ARS (Rescue and Salvage Ship)

The MSC's four rescue and salvage ships are the USNS Safeguard, USNS Grasp, USNS Salvor, and USNS Grapple. The mission of the T-ARS ship is to assist disabled ships, debeach stranded vessels, fight fires alongside other ships, lift heavy objects, recover submerged objects, tow other vessels, and perform manned diving operations ("U.S. Navy Diving Manual" 2008). To complete these tasks each ship is equipped with a towing system that incorporates a double drum, automatic towing winch, and traction winch. These winches, along with a bollard pull of 65.5 tons, gives the T-ARS class of ships the ability to tow ships as large a Nimitz class carrier. The T-ARS class ships carry a complement of divers to perform underwater ship husbandry tasks and salvage operations, as well as underwater search and recovery. This class of vessel is equipped for all air diving techniques. Onboard equipment allows diving with air to a depth of 190 fsw ("U.S. Navy Diving Manual" 2008).

Figure 3. USNS SAFEGUARD T-ARS 50 (Hurst).

This added diving capability is made possible because of a complex diver's life-support system that is integrated directly into the ship. The dive system is capable of supporting up to six divers. Each ship has a fixed decompression chamber, with a primary 300psi medium pressure air and 3,000psi high pressure secondary air (Southworth 2008). The layout of each ship is such that at the forward part of the fantail, there are davits for lowering and raising the stage diving system. A detachment of sailors from the MDSU can augment the crew for deployment and emergent salvage operations. Table 2 is a listing of the basic T-ARS ship specifications.

T-ARS (Rescue and Salvage Ship)	
Length:	255 feet
Beam:	51 feet
Draft:	17 feet
Displacement:	3,282 tons, full load
Speed:	14 knots
Civilian:	26 civil service mariners
Military:	4
Operation:	Government-owned/ Contractor Operated

Table 2. T-ARS Specs (Service Support: Rescue and Salvage Ships).

2. Work Environment

Navy divers work in variety of environments and conditions. The majority of dives are in navigable waters inshore and offshore. Occasionally, divers may be involved in HAZMAT and nuclear diving operations where waters are highly contaminated. As the condition of the work environment varies, so must the equipment the divers use. With proper gear, divers operating on air can reach depth as deep as 285 fsw. Divers are also able to operate in a wide range of water temperatures, from temperatures exceeding 90 degrees Fahrenheit, where divers wear no thermal protection, to water temperatures below 35 degrees Fahrenheit, where a dry suit must be worn. Divers may also encounter unique and dangerous marine life while operating underwater.

3. Current Stage Model

The stage being used today is a stainless steel cage with the capability of transporting up to three fully rigged divers to and from the worksite below and the surface. The cage is lowered via the ship's onboard davits to depths up to 300 feet. The stage does not have any auxiliary system on it, and it is an open design, which exposes the diver to the surrounding environment. The stage has a maximum working load of 2700 pounds. Below is an image of the stage loaded with two divers about to be lowered into the water.

Figure 4. The Navy’s Diving Stage (“Divers on stage” July 12, 2010).

D. SCOPE

The problem scope serves to limit the problem to a manageable level by focusing on the purpose of the problem. The scope should include the concerns of the key stakeholders within known limits. This thesis is to provide a proof of concept for the integration of a new SMART stage onto current dive and salvage ships, T-ARS and T-ATF class. Investigating the practicality and benefits of installing alternative SMART stage systems compared to the current stage. To accomplish this, multiple SMART stage designs will be compared and evaluated based on ease of integration, requirement satisfaction and functional design.

E. ASSUMPTIONS, LIMITATIONS, CONSTRAINTS

Several assumptions were made when addressing the problem of integrating a SMART dive cage on current dive and salvage ships. These assumptions are accepted as true or as certain to happen, without proof.

1. The Navy is investigating the use of a more advanced dive cage to improve diver performance, safety, and situational awareness.
2. The ship's power plants will not be modified; the new system will be compatible with current ship's power and auxiliaries.
3. The new system will not interfere with current capabilities of the ship, meaning the system will only enhance capabilities and not lose any.
4. Navy crew members will be the maintainers and operators of the system.
5. The design of the new SMART stage will be same for both T-ARS and T-ATF.
6. Divers will receive training on the SMART stage from the dive unit they are attached, training will not occur at dive school.

Limitations of the SMART stage are physical barriers that the system cannot break, and constraints are the rules that are placed on the SMART stage. These rules and physical barriers govern the operation of the system for safety. The SMART stage will be limited and constrained to operating under the same conditions as the current stage. The current stage operating conditions can be found in the U.S diving manual revision 6.

F. PROBLEM STATEMENT

The Navy is investigating equipping current T-ARS class salvage ships and T-ATF ocean-going tugs with a more robust diving platform. This new platform known as the SMART stage will be a modular platform that can be installed and certified on either ship platform. This thesis will explore the integration of this new system onto current ships, focusing on the additional equipment, training, maintenance, communication and space requirements. The integration of a SMART stage system is expected to improve the

overall effectiveness of divers in the water allowing them to better complete their jobs through the use of a more robust dive platform equipped with monitoring equipment and lightning.

II. STAKEHOLDERS

A. INTRODUCTION

With the problem identified, the stakeholders and their needs must next be identified. From the identified stakeholders' needs, a functional analysis of top level and supporting functions were generated, and requirements for each of the lowest level functions in the functional hierarchy were identified and documented.

B. STAKEHOLDER ANALYSIS

1. Methodology

A stakeholder analysis was conducted using the definition given in the INCOSE SE Handbook: "a stakeholder is any entity with a legitimate interest in the system" (Blanchard and Fabrycky 2011). As stakeholders were identified, they were organized into defined categories based on their interaction with the system.

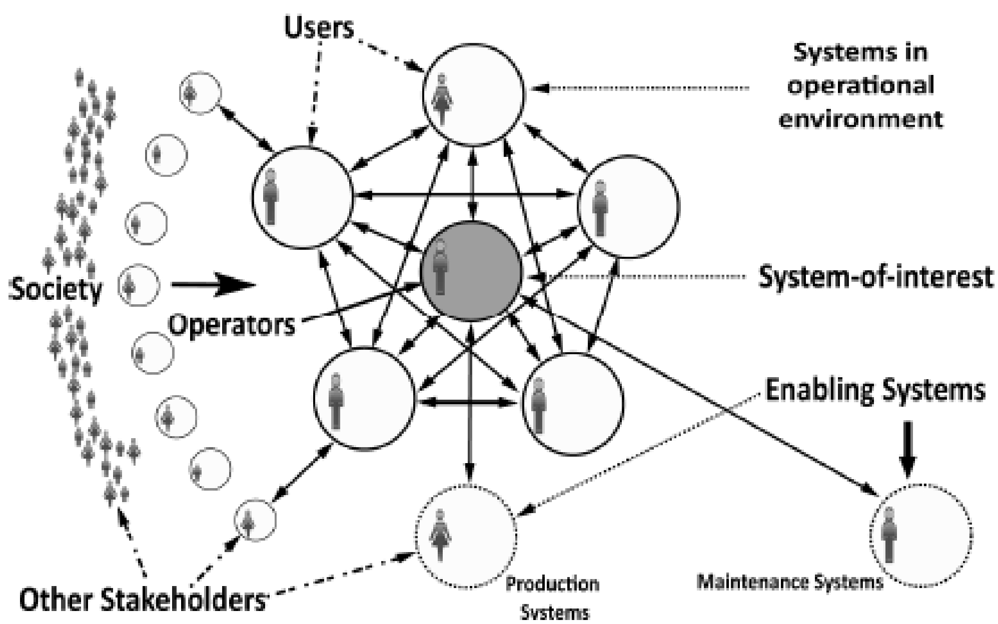

Figure 5. Stakeholder interaction with system (INCOSE, 2012).

Figure III-1 Identifies four types of stakeholders: Users, Operators, Society, and Other, and how they interact with the system.

2. Stakeholder Identification

The stakeholders that have a vested interest in this project range across a broad spectrum from user to planner. The integration of the SMART Stage into dive and salvage ships is only one element of the problem. A thorough stakeholder analysis will need to be conducted to ensure that the problem is being addressed correctly and that all key roles are being considered.

Stakeholders involved with the integration of a SMART stage were impacted by the problem different ways; some had greater needs than others. Stakeholders were broken into three main categories. The first category is comprised of the primary stakeholders, who are also the users of the system. These users have the greatest invested interest in the system because their lives may depend on how well the system operates. The primary stakeholders were identified as the divers, the dive supervisors, and the ship’s crew that directly supports the divers. The next group of stakeholders consists of the secondary stakeholders. These are the individuals, or organizations, that are removed from the system but are interested in its proper operation, utilization, and maintenance. The secondary stakeholders were identified as The Naval Diving and Salvage Training Center, salvage ships that will employ the SMART stage, shipyards, vessels in distress, and the SMART stage designers and manufactures. Lastly, the third category of stakeholders is comprised of the support stakeholders, who are concerned with the acquisition and strategic impact of the system. The support stakeholders identified are NAVSEA and SUPSALV.

C. NEEDS ANALYSIS

1. Primary Stakeholder

The needs of individual stakeholders are the most basic of needs. Primarily, these stakeholders have the most invested interest in the system, because they rely on the stages’ capabilities and proper operation from day to day. The divers who use the

SMART stage need the stage to be a safe operating platform that will aid them in completing the missions they are ordered to do. In addition to the divers, the two other primary stakeholders that have direct contact with the stage are the dive supervisors and the ship's crew.

While in the water, the divers rely heavily on their support crew above. The supervisors monitor the safety of the divers in the water. They need to keep track of precise information involving the diver's depth, water temperature, time in the water, and condition of the diver both mentally and physically. Safety is paramount, and proper monitoring of all conditions, both of the divers and their surroundings, is vital to mission safety and success. The importance of safety is also true of the ship's crew, who helps to operate and maintain the divers' life support system, as well as lifesaving equipment. Divers may operate the stage on compressed air or umbilical support. The ship's crew is there to help maintain these systems and operate them while the divers are in the water. Proper knowledge and training is required to ensure that the divers are safe and, in the case of an emergency, receive the help and support needed.

2. Secondary Stakeholders

The secondary stakeholders are identified as: The Naval Diving and Salvage Training Center, salvage ships, shipyards, vessels in distress, and the SMART stage designers and manufactures. These stakeholders have more complex needs and are more interested in the proper use of the system by the primary stakeholders. The secondary stakeholders do not directly use the SMART stage, but they are still invested in the added capabilities of the new system, as well as its safe operation. The training center is interested in ensuring that divers are fully trained in the safe operation of the new stage and that the divers are able to utilize the new features to their fullest extent. The added capabilities of the SMART stage are also in the best interest of ships in distress, such as vessels that are downed, grounded or in need of emergency repair. With the added amount of video sensors and additional tool capabilities, the crew above can help the divers in the water assess the damage, give guidance, and monitor progress.

In order to have all of the added capabilities, there are three more secondary stakeholders who must be considered. The designers and manufacturers of the new SMART stage system need to design a system that works with the current dive and salvage ships, while at the same time provide the divers with added capabilities they require. The T-ATF and T-ARS class ships need a system that can easily be integrated into their current systems without the addition of shipboard auxiliary equipment. Lastly, the shipyards need a system that is portable and easily installed onto each class of ship. The SMART stage will need to be permanently installed on the T-ARS and temporarily installed on T-ATF based on emergent needs of the navy.

3. Sponsor Stakeholders

In the remaining group of stakeholders, there are the sponsor stakeholders who are defined as: NAVSEA and SUPSALV. The sponsor stakeholders are involved with the acquisition of the new SMART stage and the strategic impact that this new asset will provide. These two sponsors are the big picture stakeholders; they need the system to be effective at providing the navy with increased dive and salvage capabilities around the world while still remaining a cost effective alternative that provides a long life cycle.

Once all important stakeholders are identified, a table containing the needs and objectives of each stakeholder was able to be generated. Table 3 is a detailed listing of the three categories of stakeholders and their needs and objectives defined.

	Stakeholder	Needs	Objectives
Primary Stakeholders	Navy Divers	Additional lighting	Have increased lighting in the workspace in order to work more efficiently and safely
		tool storage system will umbilical support on the stage	Easily assessable tools from the stage, less clutter in the workspace
		integrated umbilical life support	provide the divers with breathable air and communication with the ship above without interruption.
	Navy Dive Supervisor	precise readings of SMART stage environmentals	receive accurate data on depth/temp of water to ensure divers are operating within acceptable safety ranges
		maintain situational awareness of divers in water in relation to the SMART stage and work site	Have increased surveillance and knowledge of the divers and worksite
		communication with divers in the water	monitor divers cognitive skills and communicate information
	Ship's Crew	Knowledge on proper operation of shipboard diving equipment	provide the divers with support from ship.
Secondary stakeholders	Naval Diving and Salvage Training Center	capable stage to train divers with	Maintain mission readiness without sacrificing training
		A safe Stage integrated with tools	Provide an efficient more organized workspace for the divers
	Salvage Ships	A Stage that can be integrated into current ship systems	Maintaining/improving current mission capabilities
	Shipyards	Stage that is modular and portable	Reduce setup times installing system on ship
	Downed/damaged/grounded vessels	provide effective means for salvage/repair/removal	Ensuring the divers have the tools necessary to complete the mission
	SMART Stage Designers/Manufactures	Provide the US Navy with a quality stage	Capture a portion in the stage construction industry
		Have the stage meet the requirements and budget on time	Remain profitable
Sponsor Stakeholders	NAVSEA	acquire a stage that is effective safe and reliable	a system that provides added capabilities, is safe and has a long lifecycle
		Cost effective system that meets requirements	A system that has a low Life cycle cost
	SEA 00C2 Supervisor of Salvage and Diving (SUPSALV)	Provide the US Navy with increased dive and salvage capabilities	Increase the of divers' efficiency and effectiveness, new mission capabilities
		A System that is modular and interoperable between T-ATF and T-ARS class ships	A system that can work with both classes of dive and salvage ships with little to no modifications

Table 3. Stakeholders and Needs

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III. FUNCTIONAL ANALYSIS

Functional analysis and allocation is an essential part of the Systems Engineering process. In the preliminary phases, functional analysis is fed by high level actions or operations the system must perform to effectively address the problem. In later stages, it provides a framework to bridge the problem definition, stakeholder needs, and requirements to solution centric design and physical allocations [10]. Broadly, this analysis lays the foundation for the system's functional architecture which will be evaluated more completely in a later portion of this report.

A. FUNCTIONAL DECOMPOSITION

Based on the scope of the given problem, the functional analysis was bounded to integrating the SMART stage system onto the two dive and salvage platforms (T-ARS and T-ATF) that the navy operates. A high level functional analysis was performed to identify the top level functions as well as the sub functions regarding the integration of new SMART stage system. The highest level function is the desired end result, for this F.0 is defined as the Integrated SMART stage. This top level function is then broken down in four main functions, F.1 Installation, F.2 Training, F.3 Operation, and F4 Maintenance and Storage. These main functions were then broken down further to the subfunction level. From this level, requirements could be generated to achieve the desired function. Below is the functional decomposition that maps out all functions and subfunctions regarding the integration of a SMART stage.

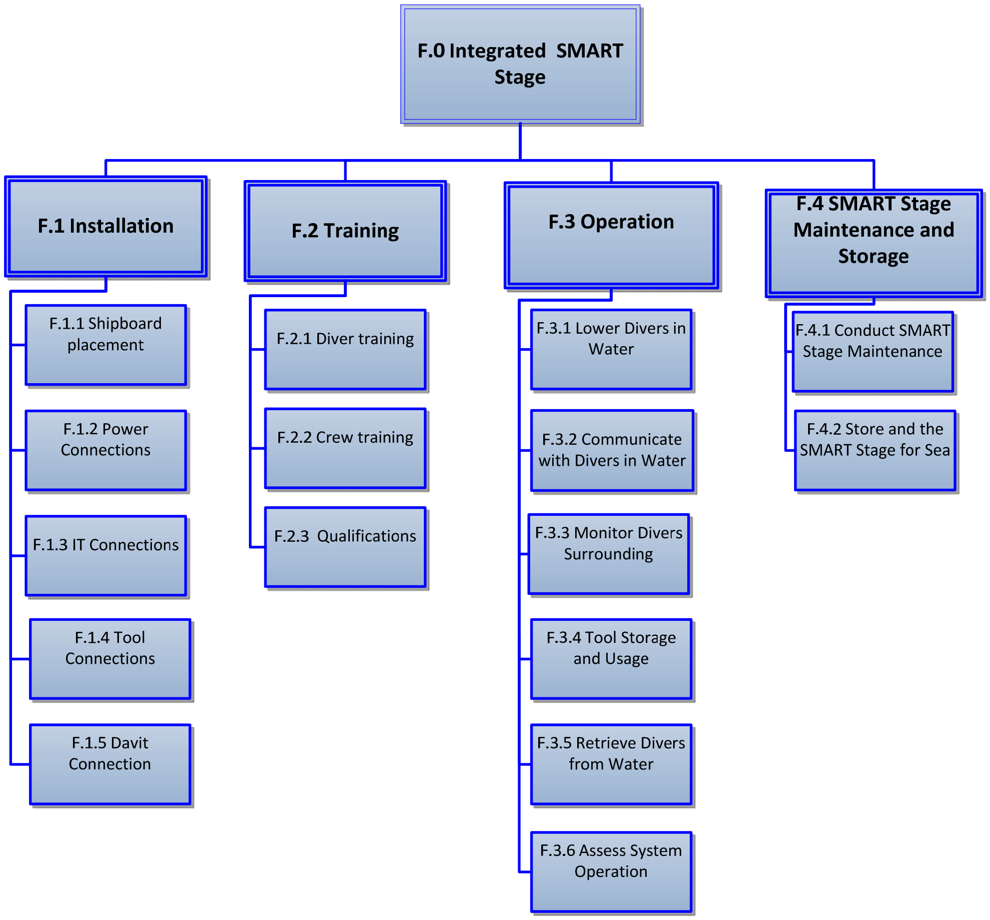

Figure 6. Functional Decomposition

B. FUNCTIONAL DEFINITIONS

In order to build requirements from these functions, each function must be well defined from the top level down. Below are the top level functions and their definitions. These top level functions are then broken down further to sublevel functions, which are then used in requirement generation.

Function 1.0 Installation – This high level function covers the majority of aspects concerning the physical placement of the SMART stage and all of its equipment onboard current T-ARS and T-ATF ships.

Function 2.0 Training – This is the high level function which captures all aspects of training and qualifications that are associated with the system. This includes the divers and the crew who supports the divers. Dive operations and safety procedures are designated in the Dive Manual.

Function 3.0 Operation– This function deals with the SMART stage in operation and the use of both the shipboard systems and the SMART stage systems to complete assigned missions. The interaction between the stage, crew, divers, and ship all fall under the operation function. The support crew is responsible for the safe operation of shipboard equipment that directly supports the divers, and the divers rely on that support as well as the capabilities of the SMART stage to complete the mission.

Function 4.0 Maintenance and Storage of SMART Stage – This Function covers the upkeep and maintenance of the system while not in use. Properly maintaining the system ensures diver safety and a long life cycle for the system. Additionally, secure storage of the system will ensure crew and system safety while underway.

Table 4 is a full listing of each function and subfunction, along with the definition pertaining to each. These functions, along with the stakeholder analysis, were then used to generate the requirements for the SMART stage system.

Function	Name	Definition
F0.0	Integrated SMART stage	Final integrated product, SMART stage installed and used onboard T-ATF and T-ARS class ships.
F1.0	Installation	The physical placement of the SMART stage and all of its equipment onboard dive and salvage ships
F1.1	Shipboard Placement	Placing the SMART stage on Dive and salvage ships in a location that is large enough to support it as well as an area that has davit and power access
F1.2	Power Connections	Connections that supply power from the ship to the SMART stage.
F1.3	IT Connections	Communication connections from the ship to the SMART stage. These connections include voice, video and data.
F1.4	Tool Connections	Connections that supply power(pneumatic or hydraulic) to tools equipped to the SMART stage.
F1.5	Davit Connections	Connection from the davit to the SMART stage. This connection will allow the stage to be raised and lowered.
F2.0	Training	The teaching of safe operation for operators of the system
F2.1	Diver Training	Ensuring that the divers are fully versed in all aspects of the SMART stage operation, to include all onboard systems and their proper use.
F2.2	Crew Training	Ensuring that the crew is well versed in the operations of the SMART stage. This includes operation of equipment to raise and lower divers, provide air and monitor/communicate with divers.
F2.3	Qualifications	A accounting system that ensures maintainers, operators and supporters are qualified to safely used the system.
F3.0	Operation	The physical operation of the system in the field.
F3.1	Lower Divers into Water	With the use of davits lowering the SMART stage system with diver crew onboard into the water.
F3.2	Communicate with Divers in Water	Communication with the divers through the use of IT equipment.
F3.3	Monitor Divers Surroundings	Visually monitor divers while in water through the use of video cameras and lighting as well as monitoring their surroundings through onboard environmental sensors.
F3.4	Tool storage and usage	Using onboard tools to complete missions and convenient secure storage while transiting to and from worksite.
F3.5	Retrieve Divers from Water	With the use of davits retrieve the SMART stage system with diver crew onboard into the water.
F3.6	Assess System Operation	After each mission the review of data collected and the assessment of the dive.
F4.0	SMART Stage Maintenance and Storage	Proper upkeep of the system while not in use
F4.1	Conduct SMART Stage Maintenance	The maintenance of the entire system to ensure safe operation and long lifecycle
F.4.2	Store the SMART Stage for Sea	While underway ensure the system is securely fastened down and secured for sea, and does not obstruct other ship missions.

Table 4. Functions and Definitions

C. FUNCTIONAL FLOW

Once all of the functions have been identified and defined, a top level functional flow block diagram was created. A Functional Flow Block Diagram (FFBD) is used to show the sequence of all functions to be accomplished by a system. A FFBD of the SMART stage shows the interaction of the high level functions with each other while integrating the system into a ship. The first function is to install the SMART stage onto the ship. Once the system has been installed the personnel who operate and maintain the system must be trained. This important step of training and qualifying personnel to operate the system is vital to integrating the system. Without properly trained individuals operating the system then next function of operating the system could not be accomplished safely. The function of operating the system involves both the support crew above and the divers in the water. The added systems that make the SMART stage smart also allow for the system to operate more efficiently, safely and effectively. This is done through instant feedback from the array of added sensors mounted on the stage. This data collected is then used to perform system assessments after each mission. The lessons identified are then reviewed for future missions with the intent that operators will learn from the past always improving. Lastly, the function of maintaining and storing the SMART stage will ensure the system's long service life. Figure 7 below is a FFBD of the SMART stage.

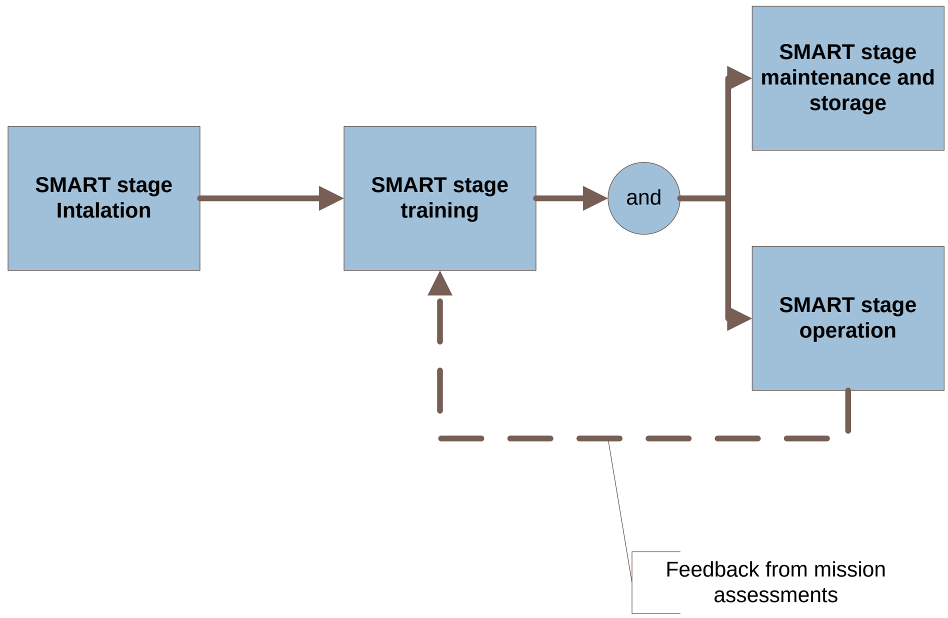

Figure 7. Functional Flow Block Diagram of SMART Stage

IV. REQUIREMENTS

A. PROCESS

To properly generate requirements for each of the functions above, basic needs were obtained through communication with the Dive and Salvage community. In addition to communications with the primary stakeholders, research into the U.S. Navy's dive manuals and ship platform specifications were used in requirement generation. Each requirement generated was mapped back to a subfunction to ensure complete coverage. A full listing of requirements is found in Table 5.

B. REQUIREMENT GENERATION

<u>Function 1.0 Installation</u>

When installing a new system onto an older platform, it is critical to know the dimensions of the system as well as the area that is available for the system. Along with size constraints, there are power and weight constraints that must be investigated to insure safe operation. A determination was made that there would be no changes made to the ship where the SMART stage system would be installed; the new system would have to be "plug and play." The new system will be required to simply plug into the ship's available power and support systems without modification. Another requirement is that the installation of the system must not diminish any of the current capabilities that the T-ATF and T-ARS possess. The requirements were then generated to meet all subfunctions regarding ship installation.

<u>Function 2.0 Training</u>

When integrating a system into a ship, there are many physical connections that must be made. There are also a number of non-physical connections that must be developed between the users and the system. The development of these connections is through the process of training and qualifications. The proper use and maintenance of a system is learned through the qualification process. The new SMART stage will also require standard operating procedures (SOP's) to ensure the system is being used

properly. In order to generate proper training requirements, the navy's dive manual was used.

Function 3.0 Operation

In the generation of operational requirements, communication with the system operators was vital. From this interaction, a list of capabilities the diving community would like to achieve was developed, allowing the requirements to be generated. In addition to speaking with the primary users, a detailed look into the dive and salvage missions were performed. These missions were then reviewed, and the basic actions needed to complete the mission were identified. These basic actions were then developed into the requirements the system requires. As a guideline, the operation capabilities the new system provides should be an improvement on that of the current system.

Function 4.0 Maintenance and Storage

For the system to be truly integrated into a ship, it must be properly maintained and stored when not in use. The system must be properly secured while underway to ensure ship, crew, and system safety. The system must also be able to be maintained in order to ensure safe operation and a long life cycle. The system will be required to have a planned maintenance system and a development of maintenance requirement cards (MRC's). Along with a maintenance schedule for the system, the crew will also have to be qualified to perform the maintenance properly.

C. REQUIREMENT IDENTIFICATION

After the analysis of the systems top level functions was completed, the requirements associated with each function were determined. These requirements are mapped directly with the functions that were previously identified above. The table below shows the requirements generated and the function associated with it. From this listing of requirements further analysis was conducted to verify that the requirements are correctly identified and the stakeholder's needs are met.

#	Requirement	Maps to Function #	Top Level Function
1	The System will portable and able to be installed on either T-ATF or T-ARS ships	F1.0	INSTALATION
2	The system will fit within the allotted space on either T-ATF or T-ARS class of ship	F1.1	
3	The system will use standard power connections	F1.2	
4	The system will connect to shipboard display equipment	F1.3	
5	The system will use standard tool connections to operate tools	F1.4	
6	The system will have connections for the shipboard davit	F1.5	
7	The system will provide training manuals and SOP's	F2.0	TRAINING
8	Divers will be trained on operation of system's features and equipment	F2.1	
9	Crew will be trained on the safe operation of stage controls	F2.2	
10	The system will use a qualification process to certify users	F2.3	
11	The system will be operated by ships crew and navy divers	F3.0	OPERATION
12	The system will be lowered into the water using cranes, davits or winches	F3.1	
13	The system will provide communication between divers in the water and support crew above.	F3.2	
14	The system will provide monitoring capabilities of the divers in the water to include, video, sonar, depth, temperature and current	F3.3	
15	The system will provide tool power and storage	F3.4	
16	The system will be recovered from the water using cranes, davits or winches	F3.5	
17	The system will record monitoring data to allow for mission assessment	F3.6	
18	The system will be maintained and stored by ships crew and navy divers	F4.0	MAINTENACE & STORAGE
19	The System will be able to be maintained while deployed	F4.1	
20	The system will be properly secured while underway ensuring safety and functionality for the ship and crew	F.4.2	

Table 5. SMART Stage System Requirements

D. REQUIREMENTS ANALYSIS

Once the requirements are generated from functional stakeholder analysis, they will need to be verified. This verification process involves defining measures of effectiveness (MOE) and measures of performance (MOP). A MOE is how well the system is able to perform a mission. A MOP measures system-particular performance parameters. MOEs are used to measure top level functions, and MOPs measure the performance of subfunctions that make up a top level function.

1. Measure of Effectiveness

Measures of effectiveness were developed for each of the top level functions of the SMART stage. Table 6 shows the mapping between function MOEs and their corresponding requirements. Additionally, metrics used to assess MOEs are identified along with thresholds and goals.

Function	Name	MOE	Metrics	Threshold	Goal	Req's
F1.0	Installation	Ability to install SMART Stage system on T-ATF and T-ARS ship platforms	size, weight, connections, power	90%	100%	1,2,3,4,5,6
F2.0	Training	Ability to train divers and support crew on safe operation and maintenance of the SMART stage system	test, qualifications, documentation	80%	90%	7,8,9,10
F3.0	Operation	Ability to operate the SMART stage system and all of its equipment safely and effectively	user proficiency, mission success rate,	85%	95%	11,12,13, 14,15,16, 17
F4.0	SMART Stage Maintenance and Storage	Ability to maintain and securely store the SMART stage	documentation, qualifications, system performance, system	90%	100%	18,19,20

Table 6. SMART Stage MOEs

2. Measure of Performance

Measures of performance were developed for each of the subfunctions that support and make up the top level functions. The MOPs listed in Table 7 measure specific operations or tasks that the system must perform. These MOPs are then mapped to the specific requirements to which they correspond. Each MOP was given a defined threshold and goal, which will be used later in the analysis of alternatives, to determine to what degree the requirement is or is not met.

Function	Name	MOP	Metrics	Threshold	Goal	Req's
F1.1	Shipboard Placement	Percentage of SMART stage system and equipment able to be installed onboard	Dimensions, weight	100%	100%	2
F1.2	Power Connections	Percent of error-free designs	Design specifications	100%	100%	3
F1.3	IT Connections	Percent of error-free designs	Design specifications	90%	100%	4
F1.4	Tool Connections	Percent of error-free designs	Design specifications	80%	100%	5
F1.5	Davit Connections	Percent of error-free designs	Design specifications	100%	100%	6
F2.1	Diver Training	Percent of divers able to effectively utilize SMART stage system	test, exercises	80%	100%	8
F2.2	Crew Training	Percent of crew able to operate SMART stage system	test, exercises	80%	100%	9
F2.3	Qualifications	Percentage of qualified user/operators	documentation	80%	100%	10
F3.1	Lower Divers into Water	Percentage of successful SMART stage deployments	number of operations	100%	100%	12
F3.2	Communicate with Divers in Water	Percent of reports sent compared to reports received	audio input and output	95%	100%	13
F3.3	Monitor Divers Surroundings	Degrees of video coverage from the stage	degrees	90°	360°	14
F3.4	Tool storage and usage	Number of tools the system can store and supply power to	amounts	1	4	15
F3.5	Retrieve Divers from Water	Percentage of successful SMART stage retrievals	number of operations	100%	100%	16
F3.6	Assess System Operation	Percentage of data successfully recorded	data received and stored	80%	100%	17
F4.1	Conduct SMART Stage Maintenance	Percentage of successful maintenance actions conducted	documentation	90%	100%	19
F.4.2	Store the SMART Stage for Sea	percentage of safely storing the SMART stage system for sea	number of operations	100%	100%	20

Table 7. SMART Stage MOPs

V. OPERATIONAL CAPABILITIES AND CONOPS

The concept of integrating the SMART Stage into the current T-ATF and T-ARS ships is to provide the Navy with added dive and salvage capabilities. These added capabilities are expected to improve the mission effectiveness of dive and salvage ships both stationed and deployed around the world. Concepts of operations (CONOPS) are generated to demonstrate how the integration of a new SMART stage dive system may provide added capabilities to the Navy. Three CONOPS were developed in order to demonstrate how the system will perform.

A. OPERATIONAL CAPABILITIES

1. Modular Deployable System

The current dive stage used by the dive and salvage communities is a modular system that is able to be used on both T-ATF and T-ARS classes of ships. In addition to ships, the system may also be used in port while pier side or on a barge that has a crane to raise and lower the stage. The stage itself is also highly deployable due to its light weight and compact size. The stage and its equipment are able to fit inside of a standard conex box shipping container. This gives the stage the capability of being easily transported around the world by air, sea or land. The new SMART Stage will also need be used in the same manner and be interoperable between each class of ship.

2. Operating Environment

The current stage is able to operate in a wide range of environmental conditions from cold waters to warm waters, fresh waters, salt waters and even in contaminated waters. The current system is able to operate at 300 fsw at the maximum extent of the divers gear. The SMART stage and its additional equipment are expected to be able to operate under these same conditions without failure or system degradation.

3. Mission Assessment

After each mission, a debrief is conducted to assess overall effectiveness of the dive and lesson identified. The SMART stage will provide the added capability of video

monitoring and recording of the divers and their conversations with the support crew on the surface. This added capability to review data from the dive can help to identify issues and concerns as well as to identify successes from each dive. The data can also be used as a training aid to distribute to other MDSU's and training facilities.

B. CONOPS

1. The SMART Stage Used for Salvage Missions

Both military and civilian ships will sometimes collide with one another or run aground resulting in the ships sinking or simply becoming stuck and requiring aid to be removed or raised. An event like this can take place anywhere around the world in nearly any large body of water. There are only eight dive and salvage ships available to the U.S. Navy with the capability of embarking a mobile dive and salvage unit along with the stage system. If the accident occurs in a remote area and the nearest dive and salvage ships does not have a MDSU onboard, a unit and system will need to be deployed to assist in the vessel salvage. The new SMART stage along with the MDSU can be flown via military cargo to the airport nearest the dive and salvage ship. Upon arrival the system and MDSU will be transported via ground transportation to the nearest port where they will be transported onboard the ship. The SMART stage system will then be installed and secured for sea as the ship steams towards the downed or beached vessel. Upon arrival at the mission site, the MDSU will deploy the SMART stage as needed using its onboard systems of lighting and cameras to assess the severity of the situation. The divers in communication with the support crew will devise a plan of action for the retrieval or removal of the vessel.

2. The SMART Stage Used to Document a Dive Mission for Training

Dive units are required to conduct exercises to maintain operational readiness and diver proficiency. With the added video monitoring capabilities and data recording of the SMART stage, a training mission can be recorded and used to train new divers. By supplying divers with a video aid prior to completing an exercise, it will allow the user to perform a desired task better than if he or she had not viewed the training video. This

ability to provide training through the use of the SMART stage's added systems helps promote diver and support crew system proficiency.

3. Smart Stage Used to Locate Sunken Vessels and Relics

Divers are tasked with many different types of missions, some of which are to locate and retrieve vessels sunk during war, both past or present. The SMART stage would offer many additional capabilities that can be used to locate hard to find or missing vessels or relics. If a MDSU was tasked with retrieval of an old WWII aircraft believed to be off the Coast of Midway Island, the added SMART systems could provide improved searching techniques. The added lighting would provide the ability to operate around the clock supplying the divers with the visibility they need to operate in the water. This coupled with the added video coverage would allow for more eyes to search the sea floor looking for debris. In addition to video search methods, imaging sonar could be employed to help locate wreckage. Upon the location of wreckage, video data could be recorded and reviewed to determine the best method of retrieval of the relic form the sea floor.

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VI. DESIGN CONCEPTS AND ALTERNATIVE SOLUTIONS

In determining various alternative solutions, information was collected on systems that are currently in use and available. Four alternatives were decided upon based on system capabilities and practicality. These four alternatives were the current dive stage, a modified version of the current system, a complete dive stage with LARS (launch & recovery system) and a completely custom system. These systems were deemed to be the most feasible systems to meet the requirements set forth by the stakeholders. Each alternative was then analyzed to determine the best solution based on three factors: ease integration, requirement fulfillment and system performance. Each alternative is further defined below.

A. IDENTIFYING ALTERNATIVES

A morphological box method was used in determining viable alternatives which could be integrated into the T-ATF and T-ARS classes of ships. A morphological analysis is a systematic search for alternative solutions. These solutions are divided into elements, and the most important characteristics are identified. Next the morphological box is formed with the characteristics and elements available. After the characteristics and elements have been identified the box is populated. Lines are then drawn from the top down combining identified characteristics and elements. The end result is an option; this option is then reviewed to see if it could be a viable alternative. This type of decision making strategy tends to produce a large number of combinations. For this thesis, only the four most feasible combinations were examined. Table 8 is an example of the populated morphological box used to determine the four SMART stage alternatives. The morphological boxes for each alternative can be found in Appendix A.

		Characteristic				
Elements	Materials	stainless steel	aluminum	titanium	wood	plastic
	Production	commercial	military	fabrication		
	Size	small	medium	large		
	Lighting Coverage	0	90	180	270	360
	Video Coverage	0	90	180	270	360
	Sonar Coverage	0	90	180	270	360
	Depth Range	100'	200'	300'	400'	
	Diver Capacity	1	2	3	4	
	Tool capacity	1	2	3	4	
	Raising/Lowering Method	crane	winch	hand	thrusters	ballast tanks

Table 8. Morphological Box for Custom Designed SMART Stage

1. Current Dive Stage

The dive stage used by the dive and salvage community is already integrated into the T-ARS class ships and is easily detachable to be used on T-ATF ships. This system provides a means to lower and raise divers in and out of the water to conduct missions. Integration is not the issue with this system because it is already in use, rather the issue is that the system does not meet all the needs set forth by the stakeholders. The system does not offer any monitoring or lighting capabilities. The current stage is reliable, easily maintained, and readily available for deployment. Figure 8 is an image of a stage system in use onboard the USNS Navajo off the coast of Oahu, Hawaii.

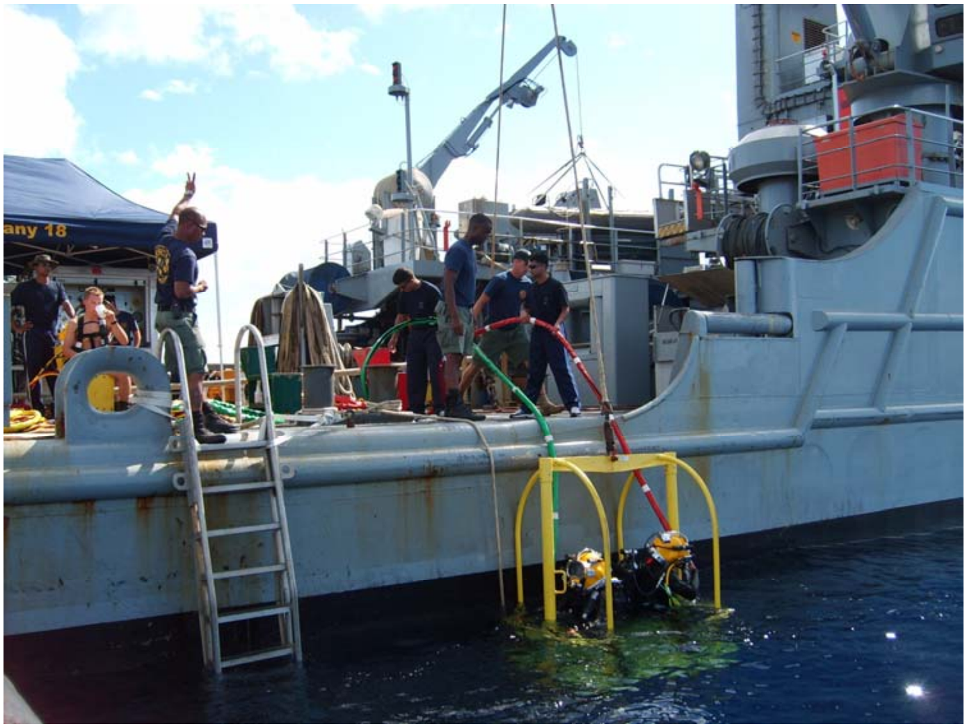

Figure 8. Current Dive Stage onboard USNS Navajo (Service Support: Rescue and Salvage Ships).

2. Modified Current Dive Stage

A modification to the current design would potentially give added "SMART" capabilities to a legacy system that is currently integrated. With the addition of lighting and video monitoring systems, a majority of requirements could be met. The dimensions for the cage would not change, nor would the systems that raise and lower it into and out of the water. The additional sensors would be added to the cage itself along with lines that supply power and data communication. This system would not fully meet all the needs of the stakeholders, but the added capabilities and ease of integration would make it a viable alternative.

3. Launch and Recovery System (LARS)

Commercial LARS type systems have been specifically designed to be compact and portable with a minimal operating footprint to save deck space on board a vessel. This versatile dive system is able to be shipped around the world due in part to its ability to fit standard intermodal containers. The LARS has the capability of folding down and

fitting into a standard 20’ conex shipping container. This system can be lightly equipped with LED lighting and video recording devices. The LARS has its own onboard hydraulic system that is used to raise or lower the stage; this allows the ship’s onboard crane to be used for other operations. The LARS offers standard power connections and detailed power requirements to operate onboard hydraulics. The most challenging integration aspect for the LARS is shipboard placement. The system has a foot print that is nearly 20’ in length and 8’ in width. The system must be placed near the edge of the ship’s deck to allow for stage deployment. System specifications for a LARS diving system can be found in Appendix B. Figure 9 is an example of a commercial LARS diving system.

Figure 9. LARS Diving System (Hydraulic Diver LARS).

4. Custom Designed Smart Stage

Last is an entirely new custom made SMART stage designed to meet all the stakeholder requirements. This would be the most robust system, and the only system of its kind. There is currently no stage system that employs all the equipment that would be needed to meet the requirements generated. This system would be the most difficult to

integrate into the current T-ATF and T-ARS ships. The capabilities that this system offers would greatly improve dive site awareness and provide the divers with a greater assortment of integrated tools. Divers would be provided a worksite that is better illuminated, and their support crews would be able to monitor the diver's surroundings through the use of sonar in murky waters and video monitoring in clear waters. Progress can be tracked more effectively, and with the aid of data recording equipment, a more thorough assessment could be conducted after each mission. A custom SMART dive system would provide the dive and salvage communities with added capabilities and improve diver efficiency and mission accomplishment. These added capabilities would require more shipboard equipment, training and maintenance checks due to the added complexities of the system.

B. ANALYSIS OF ALTERNATIVES

With the top four alternatives identified further analysis was conducted to determine the best diving stage option for Current T-ATF and T-ARS ships. This ranking of the alternatives was based upon the examination of three main grading criteria. These criteria are requirement satisfaction, ease of system integration, and system performance. These criteria were then ranked to determine weights that would be used to rank the entire system as a whole. The system that best meets these grading criteria would be deemed to be the best option for integration into the current dive and salvage ships.

1. Requirement Satisfaction

The first criterion investigated was the requirement satisfaction, which was given a weighting of 40%. The requirements taken into consideration were the operational requirements that deal primarily with the added SMART systems. The fulfillment of these requirements was then broken down into seven elements: data recording, video monitoring, sonar imaging, communications, lighting, depth monitoring and tool capabilities. Each element was then given its own weighted value based on requirement ranking of importance. The first element of data recording is an important form of system feedback that can be reviewed and used to assess missions identifying and learning from successes and failures. The next element of video monitoring makes up a majority of the

data recorded. Video monitoring provides the support crew on the surface the ability to see the divers and their surroundings in the water. This along with the next element of sonar imaging gives more information to the support crew, so that they can make recommendations to the divers or monitor their progress and safety. The next element of communication, verbal communication, allows for the two way communication between divers and the support crew on the surface. Verbal communication between divers and support crew is deemed to be the most important element. This is because it accounts for the main way to monitor the divers' safety. The next element is lighting. The illumination of the dive site allows the divers to see their surroundings when surface lighting is not sufficient. Lighting also directly aids the element of video monitoring by supply sufficient illumination to display images. The next element of depth monitoring is important to the system because it allows the support crew to know exactly how deep the divers are operating. There is depth limitations placed on different types of diving equipment and upon the human body. Accurate depth monitoring maintains diver and equipment safety. Lastly, the final element of tool capability is defined as the amount of tools the stage can store or for which it can provide power. The added benefits of having a system that could provide pneumatic or hydraulic powered tools would improve the diver's job performance. The divers would have the added capabilities of powered tools, along with an organized means of storing them when not in use. Table 9 shows the results of each alternative's ability to satisfy requirements.

Requirement Satisfaction weighing = .4							Req Satisfaction Value
0.05	**0.1**	**0.01**	**0.1**	**0.1**	**0.02**	**0.02**	
Data recording	Video Monitoring	Sonar Imaging	Communications	Lighting	Depth Sensor	Tools	
0	0	0	3	0	0	0	0.3
3	3	0	5	3	5	1	1.37
3	3	0	2	2	5	3	1.01
5	5	5	5	5	5	5	2

Table 9. Requirement Satisfaction Ranking

2. System Integration

The next criterion of system integration was again given weighting of 40%, making it just as important as the requirement satisfaction. The integration of the SMART stage was broken down into the four most basic elements of equipment, space, connections and training. The individual elements were then given weighted values based upon their overall importance to the system's integration. With a new system, there is additional technical equipment that will be needed to be installed on the ship to collect data from the SMART stage's sensors. The placement of the added equipment deals with the next element of space. There is a limited amount of space that the system is allowed to operate within without interfering with other ship functions. The space required by the SMART stage must incorporate all the additional systems that are needed to operate it. This leads directly into the next element of connections. These physical connections that connect the SMART stage system to the ship are critical for integration. The connections supply the SMART stage with power, air, communication, data and a means of transportation into and out of the water. In addition to physical connections, there are non-physical connections in the form of the final element, training. Training is a means that connects the system to the users. Proper training will allow the ship to fully utilize the SMART stage system effectively and safely. The Table 10 shows the results for the ease of system integration for each alternative.

System Integration = .4				Integration Value
0.1	0.08	0.1	0.12	
Equipment	Space	Connections	Training	
5	5	5	5	2
3	4	3	4	1.4
2	3	2	2	0.88
2	3	2	1	0.76

Table 10. System Integration Ranking

3. System Performance

The last criterion of system performance was given a weighting value of 20%. This criterion takes a look into the system's ability to be maintained and deployed, as well as how reliable and safe the system is. These elements were determined to be the most important aspects of system performance. The maintenance of the system will ensure that the system will operate correctly over a long life cycle. Maintenance is directly correlated to the safety of the system. A safe system is a system that is maintained properly. In addition to safety, maintenance also promotes a high level of reliability. But in terms of system complexity, a more complex system is expected to be harder to maintain and have a lower rate of reliability over a simple system. The last element of system performance is deployability. The ability for the system to be utilized anywhere around the world is dependent on how well the system can be deployed to a ship. Table 11 shows the results for each alternative and their overall system performance.

System Performance = .2				Performance Value
0.05	0.05	0.05	0.05	
Reliability	Safety	Maintainability	Deployability	
5	5	5	5	1
4	5	4	4	0.85
4	5	3	5	0.85
3	5	3	3	0.7

Table 11. System Performance Ranking

C. DECIDED SOLUTION

After the analysis of alternative had been completed, a decisive winner could be clearly identified. The most viable system would be a modified combination of the current system with key added SMART technologies. This system, though it does not meet all the user requirements, would be the most practical option to employ SMART systems . The operation and maintenance of the current stage is already understood by divers and support crews. This means that the system is already integrated into the current ships and its users. The only portions not currently integrated into the ships are the additional connections for the added systems and the monitors and computers used to view and record data from the SMART stage. The added equipment does not require a lot of space nor will it require extensive training regarding operation. The added features of 180^o lighting and video coverage, data recording and basic tool storage satisfy a majority of the stakeholders' requirements. The final result of the analysis of alternatives is seen in Table 12.

Alternatives	Integration Value	Req Satisfaction Value	Performance Value	Final Score
Current System	**2**	0.3	**1**	3.3
Modified Current System	1.4	1.37	0.85	**3.62**
LARS System	0.88	1.01	0.85	2.74
Custom System	0.76	**2**	0.7	3.46

Table 12. Overall Ranking of Alternatives

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VII. CONCLUSION RECOMMENDATIONS

A. CONCLUSION

After investigating various alternative SMART stages for equipping current T-ARS class salvage ships and T-ATF ocean-going tugs, a SMART stage was determined based upon three main grading criteria of requirement satisfaction, system integration and system operation. The most viable solution was identified as a modification to the current dive stage in use. This system proved to be the best solution based upon its ability to balance requirement satisfaction with system integration. This partially new system is expected to improve the overall effectiveness of divers in the water, allowing them to better complete their jobs through the use of a more robust dive platform equipped with monitoring equipment and lightning.

The ability to update the current system would alleviate much of the main system integration concerns to the ship. Integration efforts would then be directed towards installing key SMART systems on the stage itself with minimal equipment added to the ship. This would allow for the tailoring of the system with specific sensors identified by the users. The system may not meet all of the requirements, but the stage itself could act as a test platform for determining the best combination of sensors to be used on the next generation of SMART stages.

B. RECOMMENDATIONS

The dive and salvage community should explore ways of modifying their current systems rather than acquiring an entirely new system or purchasing a commercial system. By utilizing an existing system and adding specific equipment the community would benefit from the fact that the crews are trained in the operation and proper use of the stage and it is integrated into current dive and salvage ships. The selection of equipment to be added should be made by the users and the integration of the equipment should be limited to on stage at a time. This would allow for further testing and evaluation of the new systems in the field to determine if they meet desired needs of stakeholders. This incremental process would allow the stages to be developed into the optimum system.

The final system could then be used as a design plan to develop a more robust system that satisfies all integration and user requirements.

APPENDIX A. MORPHOLOGICAL BOXES

		Characteristic				
Elements	Materials	stainless steel	aluminum	titanium	wood	plastic
	Production	commercial	military	fabrication		
	Size	small	medium	large		
	Lighting Coverage	0	90	180	270	360
	Video Coverage	0	90	180	270	360
	Sonar Coverage	0	90	180	270	360
	Depth Range	100'	200'	300'	400'	
	Diver Capacity	1	2	3	4	
	Tool capacity	0	1	2	3	4
	Raising/Lowering Method	crane	winch	hand	thrusters	ballast tanks

Current System

		Characteristic				
Elements	Materials	stainless steel	aluminum	titanium	wood	plastic
	Production	commercial	military	fabrication		
	Size	small	medium	large		
	Lighting Coverage	0	90	180	270	360
	Video Coverage	0	90	180	270	360
	Sonar Coverage	0	90	180	270	360
	Depth Range	100'	200'	300'	400'	
	Diver Capacity	1	2	3	4	
	Tool capacity	1	2	3	4	
	Raising/Lowering Method	crane	winch	hand	thrusters	ballast tanks

Modified Current System

		Characteristic				
Elements	Materials	stainless steel	aluminum	titanium	wood	plastic
	Production	commercial	military	fabrication		
	Size	small	medium	large		
	Lighting Coverage	0	90	180	270	360
	Video Coverage	0	90	180	270	360
	Sonar Coverage	0	90	180	270	360
	Depth Range	100'	200'	300'	400'	
	Diver Capacity	1	2	3	4	
	Tool capacity	1	2	3	4	
	Raising/Lowering Method	crane	winch	hand	thrusters	ballast tanks
			LARS			

		Characteristic				
Elements	Materials	stainless steel	aluminum	titanium	wood	plastic
	Production	commercial	military	fabrication		
	Size	small	medium	large		
	Lighting Coverage	0	90	180	270	360
	Video Coverage	0	90	180	270	360
	Sonar Coverage	0	90	180	270	360
	Depth Range	100'	200'	300'	400'	
	Diver Capacity	1	2	3	4	
	Tool capacity	1	2	3	4	
	Raising/Lowering Method	crane	winch	hand	thrusters	ballast tanks
		Custom SMART stage				

APPENDIX B. LARS SPECIFICATIONS

Specification:
Our Diver Launch and Recovery Systems (LARS) have the following technical specification:
Depth Capability: 75 mtrs
Design: Lloyds Register Rules for Offshore lifting
Certification: IMCA D023 Design & IMCA D018
Basket / Cage Cylinders: 2 x 50 Litre @ 300 Bar
Length: 3500 mm
Width: 2100 mm
Height: 3690 mm
Weight: 4800 kgs (HPU Not Included)
HPU Electrical Requirements: 380–440 V 3PH 50/60 Hz
Oil Capacity: 2 x 200 Litre (Per Twin Tank)
Oil Delivery: 90 litres / min @ 1450 RPM max
Hydraulic Oil Cooling: 2 x Tube and Shell Seawater Oil Coolers
Hydraulic Working Pressure: 100 Bar

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